THURSDAY, JANUARY 22, 1880

ON THE PHOTOGRAPHIC SPECTRA OF STARS[1]

THE author presented, in December, 1876, a preliminary note on the subject of this paper, together with a diagram of the spectrum of Vega compared with that of the sun.

The author refers to a paper by Dr. William Allen Miller and himself in 1864, in which they describe an early attempt to photograph the spectra of stars.

Other investigations prevented the author from resuming this line of research until 1875, when a more perfect driving clock, by Grubb, enabled him to take up this work with greater prospect of success.

The author describes the special apparatus and the methods of working which have been employed.

In consequence of the very limited amount of light received from the stars, it was of great importance not to spread out the spectrum to a greater extent than was necessary for a sufficient separation of the principal lines of the spectrum. The spectrum apparatus finally adopted consists of one prism of Iceland spar and lenses of quartz. The length of the spectrum taken with this apparatus is about half an inch, from G to O in the ultra-violet. The definition is so good that in photographs of the solar spectrum at least seven lines can be counted between H and K.

Though there is considerable loss of light in the employment of a slit, still, for the great advantage which it affords in obtaining spectra of comparison, a narrow slit one-three-hundred-and-fiftieth ($\frac{1}{350}$) of an inch in width was always employed.

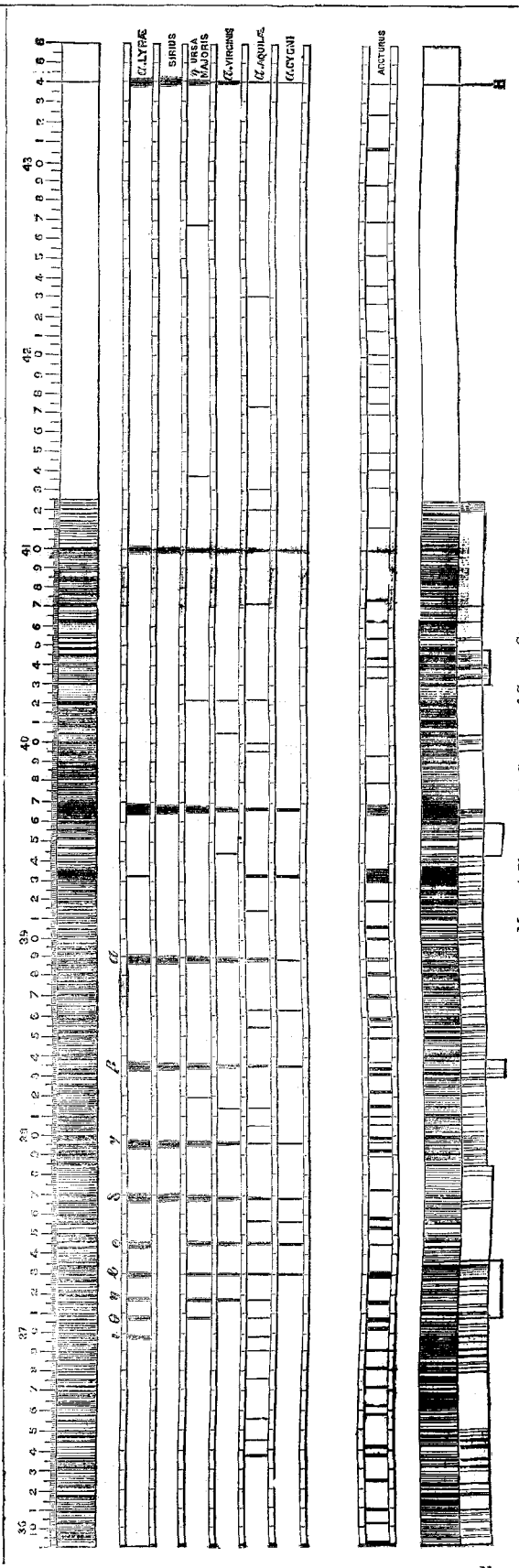
This slit is provided with two shutters. By means of these through one half of the slit a solar or other spectrum may be taken on the same plate for comparison, and for the determination of the lines in position in the spectrum. This apparatus was adapted to a Cassegrain reflector with a metallic speculum of 18 inches aperture. The small mirror was removed and the slit of the spectrum apparatus placed at the principal focus of the mirror. A simple but perfectly successful method was adopted by which the image of a star could be brought exactly upon the slit, and retained there during the whole time of exposure, sometimes for more than one hour, by a system of continuous supervision, and instant control by hand when necessary.

Various photographic methods were tried, but the great sensitiveness which may be given to gelatine plates, together with the special advantages under long exposures of dry plates led finally to the exclusive adoption of this method.

The photographs were examined and the lines measured by means of a micrometer attached to a microscope of low power. These measures were reduced to wave-lengths by the help of solar and terrestrial spectra, use being made of M. Cornu's map of the ultra-violet part of the spectrum, and of M. Mascart's determination of the wave-lengths of the lines of cadmium.

Photographs have been obtained of the stars Sirius,

[1] Abstract of paper by W. Huggins, D.C.L., LL.D., F.R.S., read before the Royal Society, December 18, 1879, with additions by the author.



Map of Photographic Spectra of Seven Stars.

Vega, α Cygni, α Virginis, η Ursæ Majoris, α Aquilæ, Arcturus, β Pegasi, Betelgeux, Capella, α Herculis, Rigel, and α Pegasi. Also of the planets Jupiter, Venus, and Mars, and of different small areas of the moon.

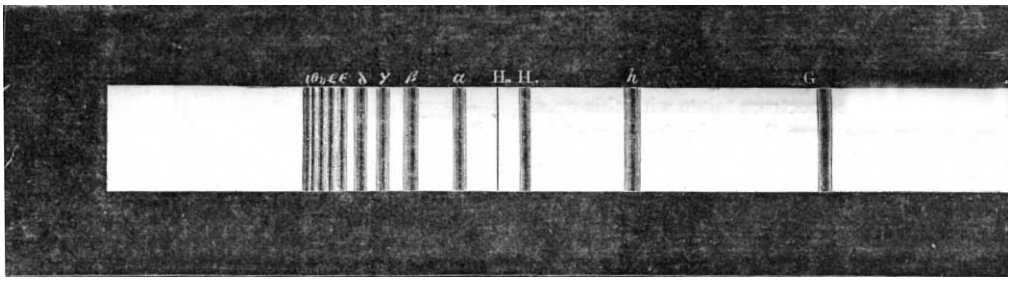
The spectra of Sirius, Vega, α Cygni, α Virginis, η Ursæ Majoris, α Aquilæ and Arcturus are laid down in the map on the scale of M. Cornu's map of the ultra-violet part of the solar spectrum.

The stellar spectra extend from about G to O in the ultra-violet.

Six of these spectra belong to stars of the white class. In 1864 the author pointed out the features in common in the visible spectra of these stars. These photographs present a remarkable typical spectrum consisting of twelve strong lines (seven only of these were given in the preliminary note in 1876). The least refrangible of these is coincident with the hydrogen line (γ) near G. The second with *h* also a line of hydrogen. The third with H. K if present at all, is thin and inconspicuous.[1]

These lines, H and K, are coincident with lines in the calcium spectrum, and are usually attributed to the vapour of this substance. Now there is another pair of strong lines in the spectrum of calcium, which in M. Cornu's map have the wave-lengths 3736·5 and 3705·5. There are no strong lines in the white stars coincident with these lines. A glance at the map will show how remarkable is the arrangement in position of these twelve typical lines. They form a great group in which the distance between any two adjacent lines is less as the refrangibility increases. It is at once suggested that they are connected with each other and represent probably one substance, and two at least belong to hydrogen.

It should be stated that the continuous spectrum extends in the photographs beyond S, but no lines can be detected beyond the twelfth line at λ 3699. For the sake of convenience of reference the author distinguishes these lines by the letters of the Greek alphabet in the order of refrangibility, beginning with the first line beyond K of the solar spectrum. The wave-lengths of these lines are as follows :—



Photographic Spectrum of α Lyræ.

1.	Hydrogen near G	4340
2.	*h*	4101
3.	H	3968
4.	α	3887·5
5.	β	3834
6.	γ	3795
7.	δ	3767·5
8.	ε	3745
9.	ζ	3730
10.	η	3717·5
11.	θ	3707·5
12.	ι	3699

In all these stars the line K is either absent or very thin as compared with its appearance in the solar spectrum.[2] In the spectrum of Arcturus, which belongs to the solar type, this line exceeds in breadth and intensity its condition in the solar spectrum. The white stars may, therefore, be arranged in a series in which the line K passes through different stages of thickness, at the same time that the typical lines become narrower and more defined, and other finer lines present themselves in increasing numbers. Arcturus seems to present a spectrum on the other side of that of the sun in the order of changes from the white-star group.

The spectra of the planets were taken on the plan suggested by the author in 1864, in which the planet's spectrum is observed or photographed together with a daylight spectrum. These photographs show no sensible planetary modification of the violet and ultra-violet parts of the spectrum of the planets Venus, Mars, and Jupiter.

Numerous spectra of small areas of the lunar surface have been taken under different conditions of illumination, and during eclipses of that body. The results are wholly negative as to any absorptive action of a lunar atmosphere.

The author is preparing to attempt to obtain by photography any lines which may exist in the violet and ultra-violet spectra of the gaseous nebulæ. He also points out the suitability of the photographic method of stellar spectroscopy, first inaugurated by his researches, to some other investigations, such as—differences which may present themselves in the photographic region in the case of the variable stars, the difference of relative motion of two stars in the line of sight, the sun's rotation from photographic spectra of opposite limbs, and the spectra of the different parts of a sun-spot.

In the hope of throwing light on many physical questions suggested by the stellar photographs, the author has taken for comparison a number of terrestrial spectra, especially of hydrogen and calcium, under different physical conditions. As he is still pursuing this inquiry, he reserves an account of this part of his work.

[1] The author refers to Mr. Lockyer's paper, *Proceed.* R. S., No. 168, 1876, in which he suggested that photographs of the spectra of the brighter stars might show modifications of this character of the lines of the calcium spectrum, and that such modifications would confirm his views on the dissociation of this substance. Reference is also made to *Proceedings* R.S., December, 1878, Fig. 1, where Mr. Lockyer gives a fuller statement of his views on this and other points in connection with different classes of spectra of the stars.

[2] Messrs. Dewar and Liveing have ound in their experiments similar relative changes of intensity of the lines of calcium corresponding to H and K in the *emission* spectrum of calcium.